Calorimeter for ILC

Status of the Micromegas SDHCAL project

European Linear Collider Workshop

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On behalf of the **LAPP LC Detector group**

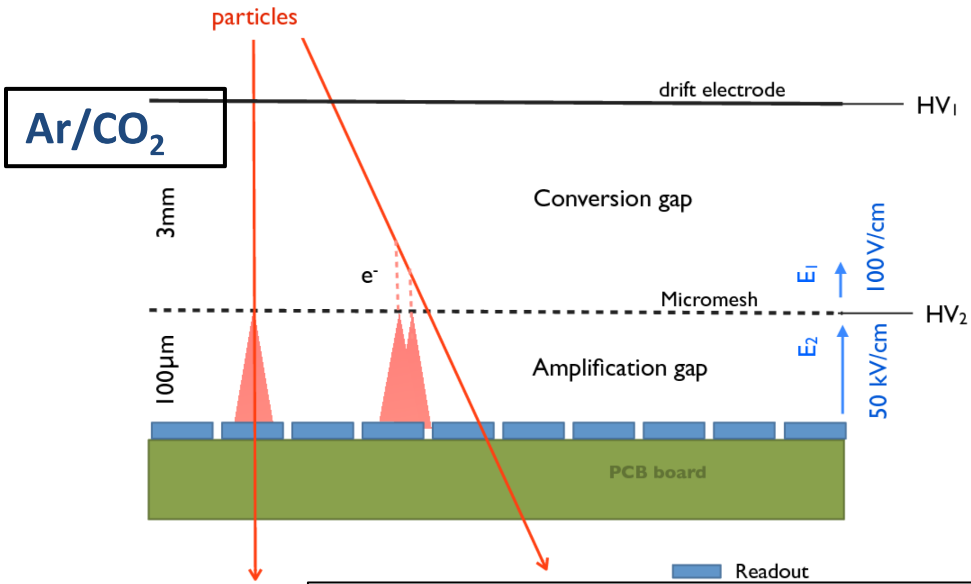
UNIVERSITE DE SAVOIE
CHAMBERY ANNECY

Overview

- Introduction
  - Micromegas detection principle
  - integration in the ILC or CLIC project
- R&D
  - large area Micromegas detectors with integrated electronics
- Test beam
  - Response to minimum ionizing particles
  - Integration into a $1m^3$ calorimeter and response to hadrons
- Simulation and offline analysis
  - Improvement of the linearity using a multi-thresholds analysis
- Conclusion and plans

Micromegas detection principle

Bulk technology fabrication by the lamination of a steel woven mesh and photo-sensitive layers on a PCB



- Ionization (30 e^- in average for MIP)
  - In a 3mm gap of Ar
  - Max drift time: 50 ns
- *Woven mesh (1.1% of pad area covered by pillars)*
- Multiplication (10^4 factor)
  - In a 128 µm gap
  - ~1 ns (100 ns for ions)

Advantages of this technology:

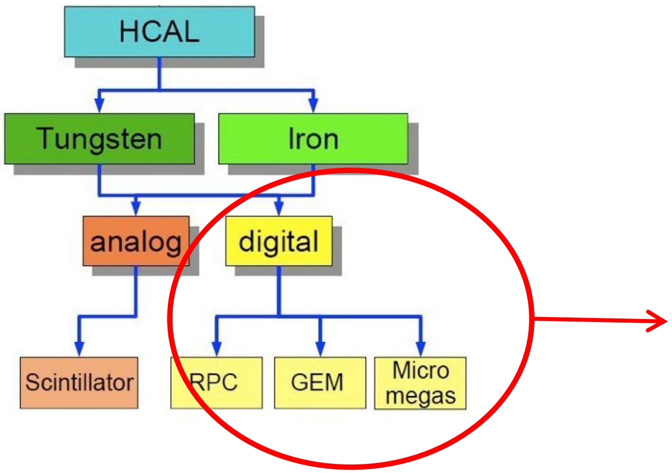
- high rate capability (> tens of MHz/cm^2)
- proportionality and negligible space charge effect
- low operating voltages (<400 V)
- low hit multiplicity (1.05 for 90° tracks)

Hadronic calorimetry in the futur LC

- Strategy for the hadronic calorimetry:

  Particle Flow technique

  - ➢ Detailed shower description more important than single particle resolution
  - ➢ Need of fine transverse & longitudinal segmentation for a good separation and particle identification

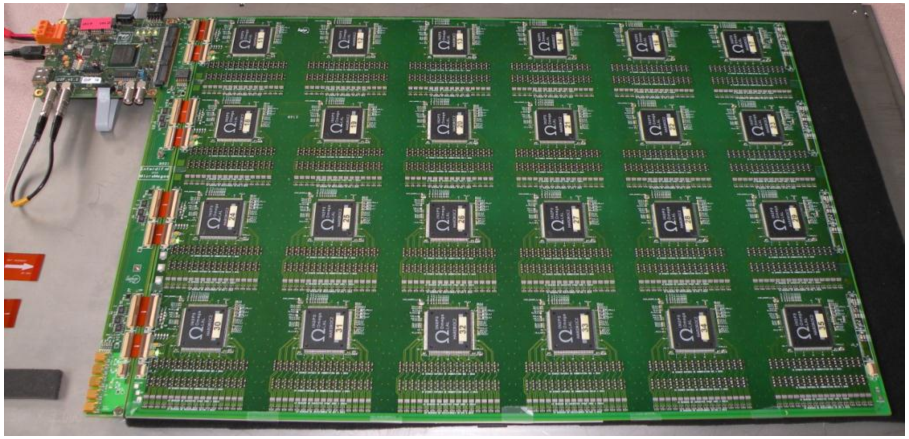


- sampling calorimeters
- 1x1 cm^2 pads
- gas detector
- digital readout

Micromegas boards

Active Sensor Units of 32x48 cm^2

= PCB with 1536 pads + 1 mesh + integrated electronics



ASU are read out by 2 boards: DIF & interDIF

The MICROROC ASIC (LAPP/Omega) and the PCB

- ✓ 64 self-triggered channels with memory and time-stamping
- ✓ Low noise charge preamplifier → 1 fC threshold (0.2 MIP)
- ✓ 2 shapers : dynamic range of 20 & 100 MIP respectively
- ✓ 3 discriminators (3 possible thresholds)
- ✓ Power-pulsing functionality
- ✓ analogue readout available on PCB
- ✓ Spark protections = 1 diode network par channel

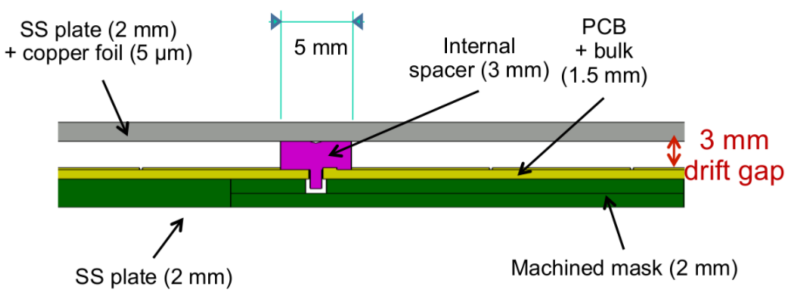
$1m^2$ chambers: geometry

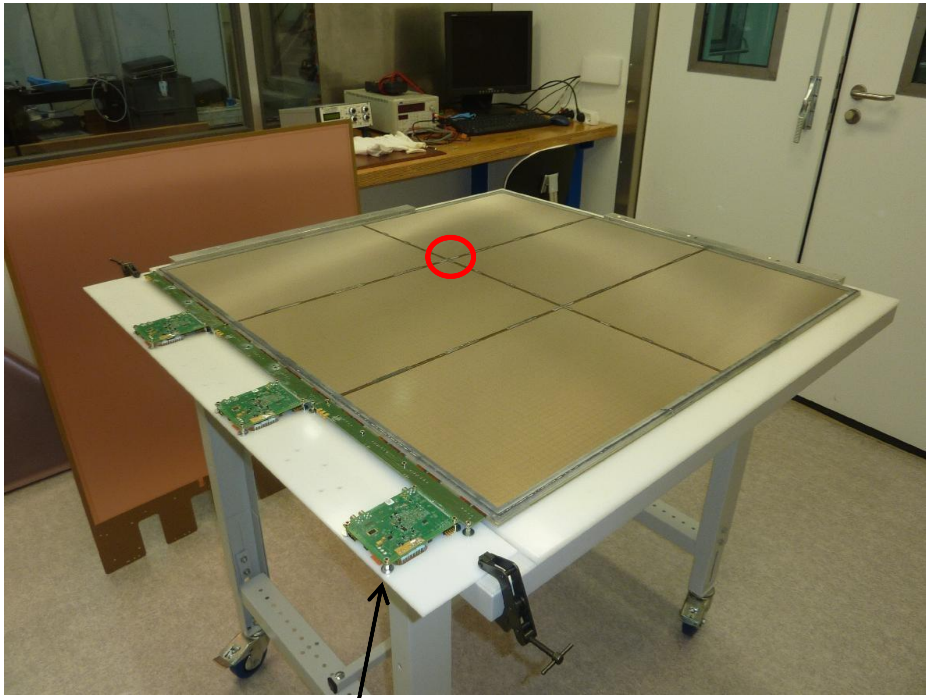
A 1x1 m^2 prototype consists of 3 slabs with DIF + interDIF + ASU + ASU

- total gas volume: 3 liters
- very little dead zone (below 2%)
- fully scalable to larger sizes

The final chamber thickness is 9 mm

The drift gap is defined by **small spacers** and a frame





Readout boards (DIF+interDIF)
Also provide ASIC LV & mesh HV

Performances using TB at CERN

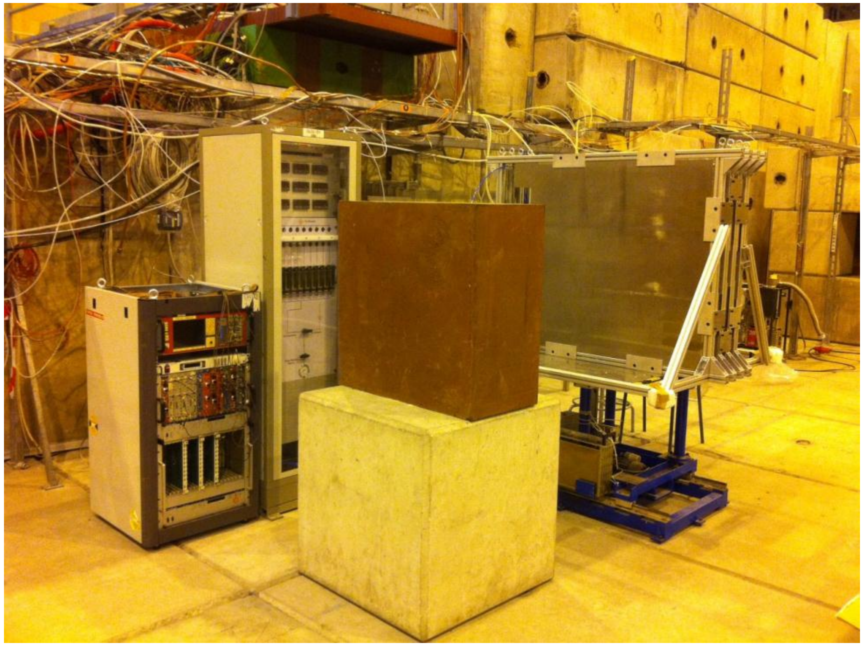
after quality checks and calibration at LAPP

Micromegas standalone:

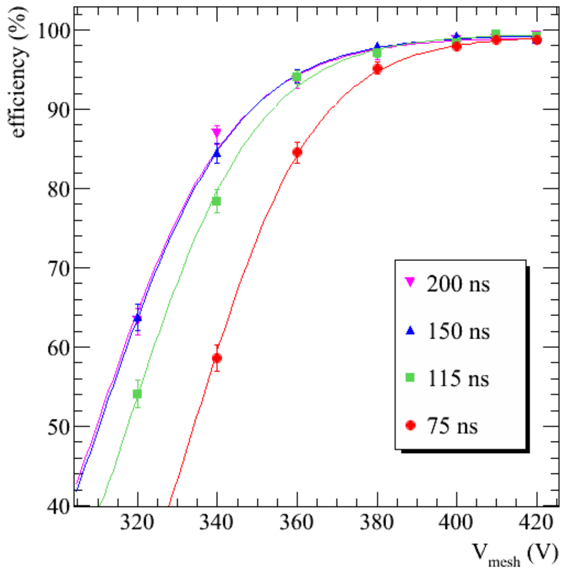
- threshold and gain setting
- efficiency
- multiplicity
- behavior under different rates

4 chambers integrated into a 50 layer calorimeter (46 RPS + absorbers)

- longitudinal profiles
- response and linearity



Muon Test Beam

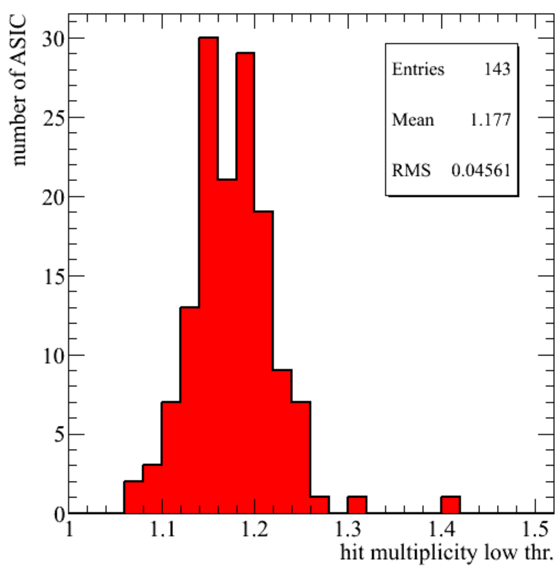


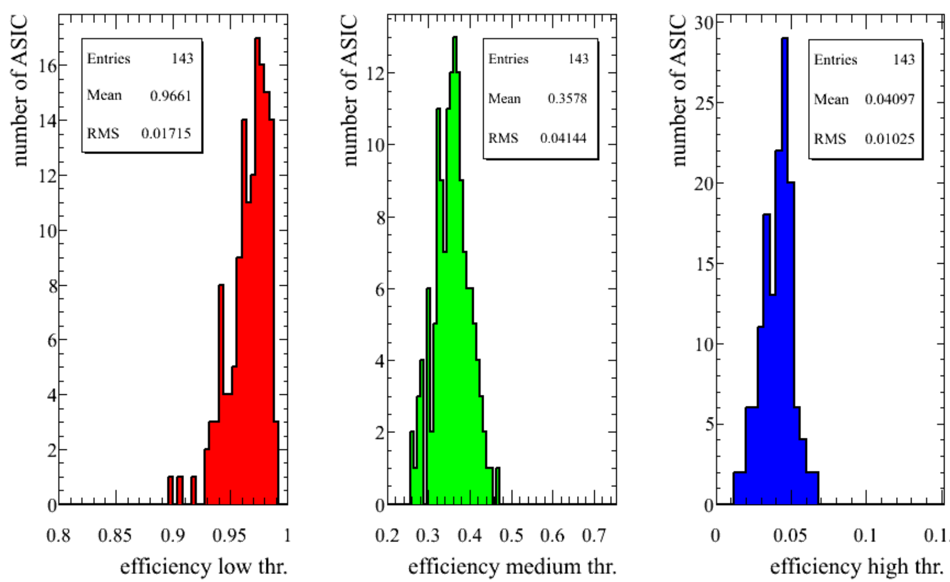
Efficaciency > 95 % beyond 365 V

Settings:
Thresholds at 0.25 , 2 , 10 MIPs
Mesh voltage at 400 V
Shaper at 200 ns

Hit multiplicity < 1.2

Variations of the efficiency : 2%, 12% and 25%





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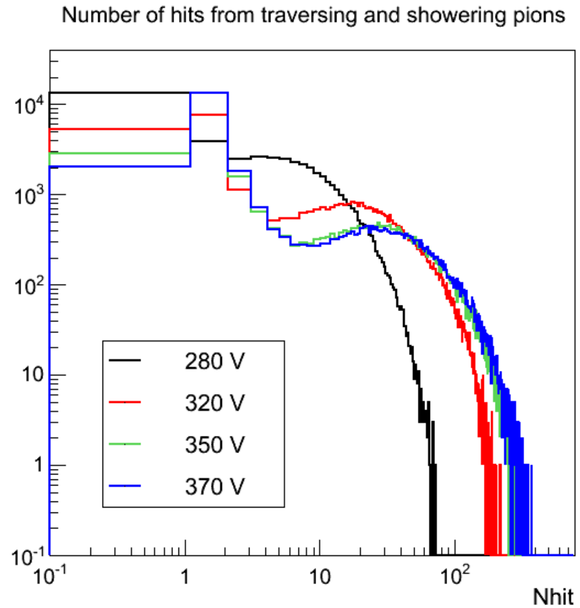
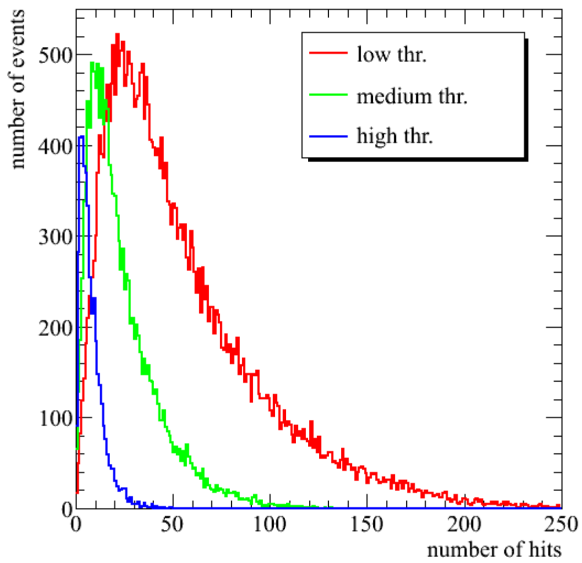
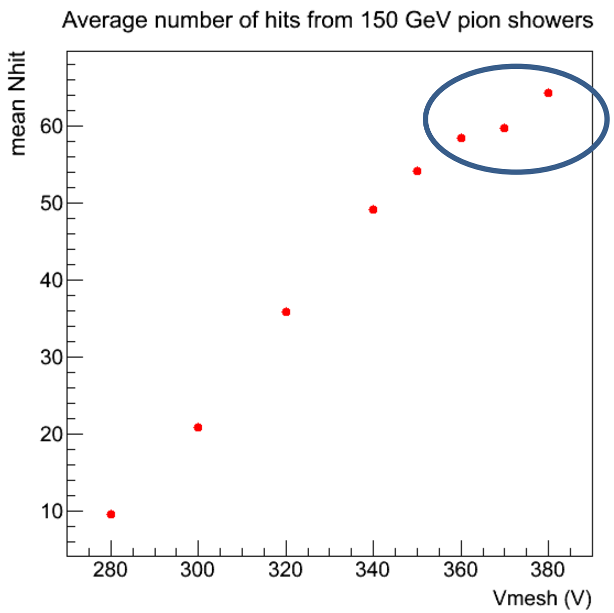
Hadronic showers





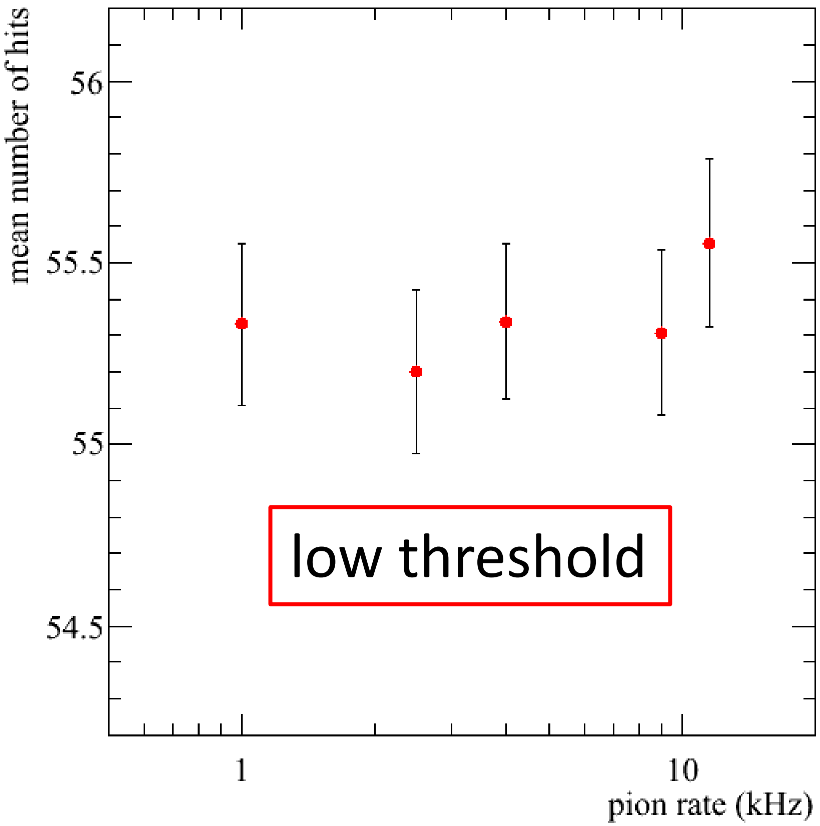


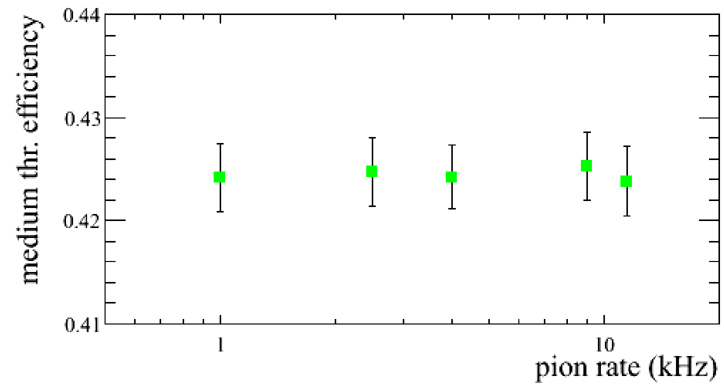
The four chambers are positioned after 2 λ_{int} of Fe, so that to study the resulting hadronic showers.

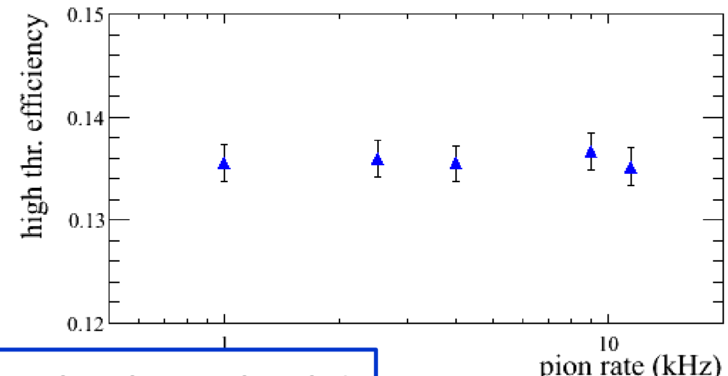
The number of hits is stabilized after a mesh voltage of 360 V. This voltage is thus enough. A higher voltage would only increase the hit multiplicity, it is thus not suggested.

Efficiency versus beam rate

medium threshold







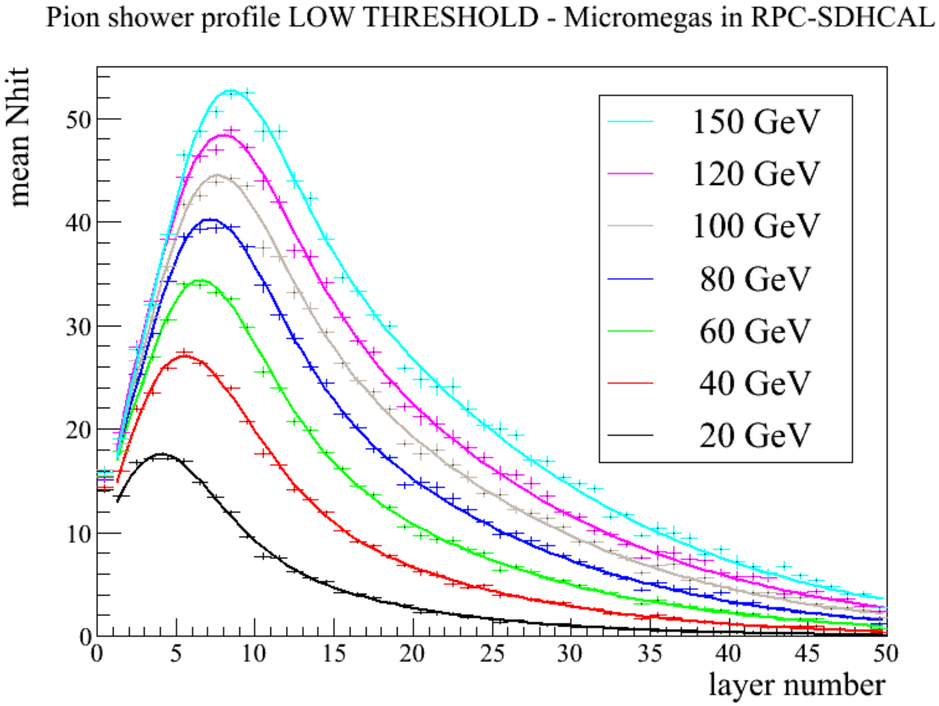
high threshold

Pions TB: shower profile

Then the four chambers are integrated into a 50 layers calorimeter.

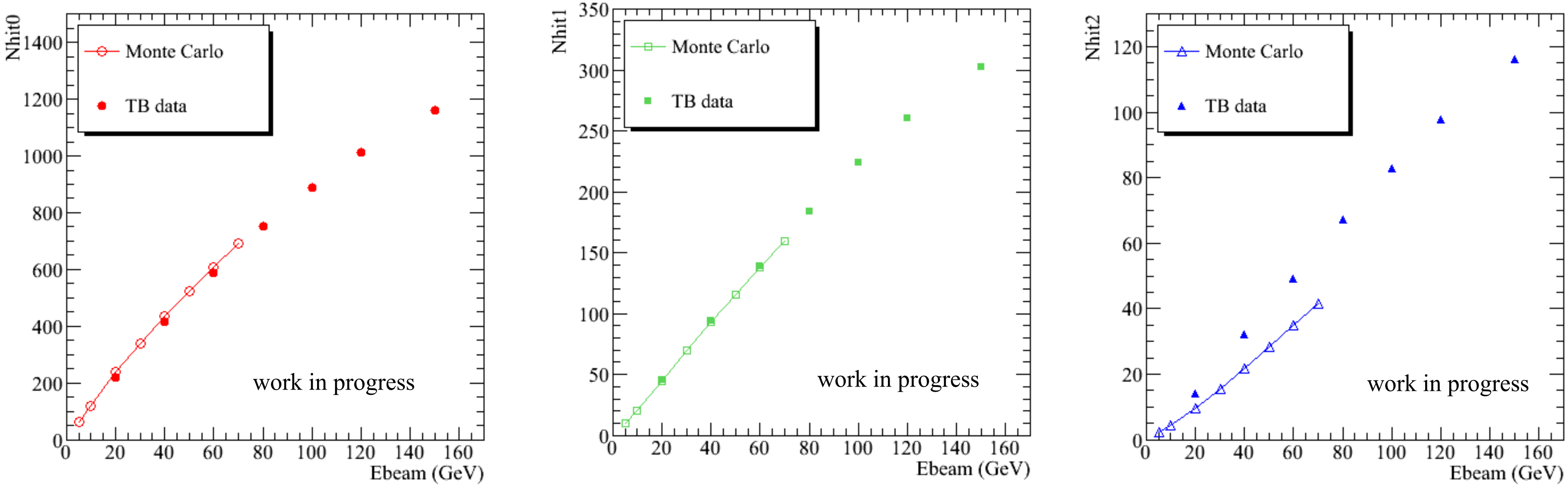
Althouhg the position of the chambers is fixed, their position is always different wrt the start of the hadronic shower.

The number of hits as a function of the distance between each chamber and the start of the shower gives the longitudinal profile of the shower.



Integrating these profiles we have the expected number of hits for every energy.

Data vs Monte Carlo simulation



low threshold

medium threshold

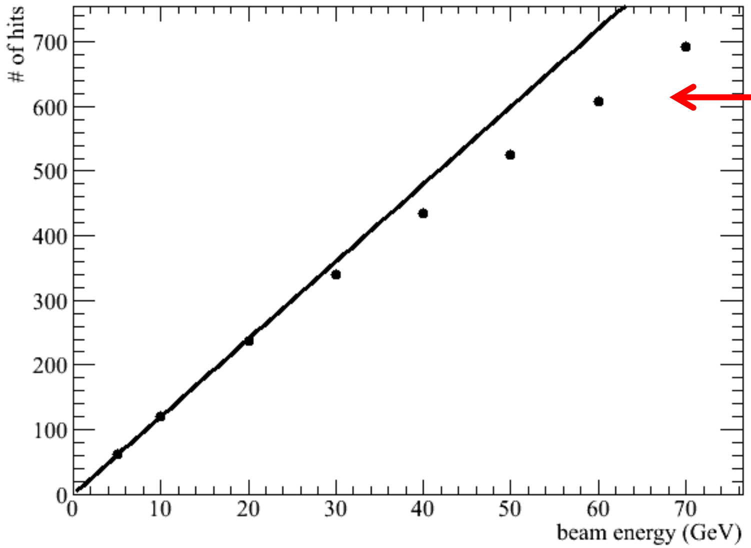
medium threshold

preliminary results

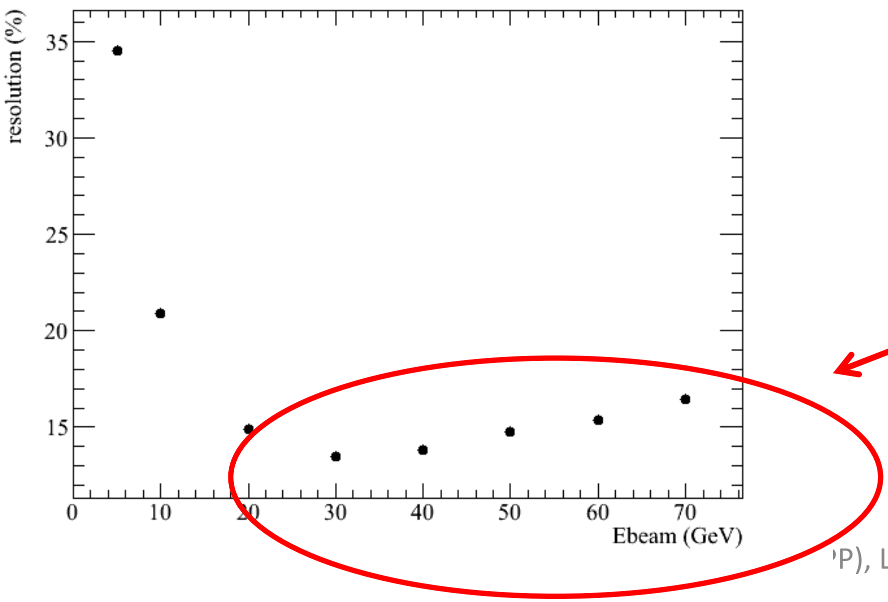
Very good agreement for low and medium thresholds.

Not very good description of the high threshold.

Expectations with a DHCAL (Geant 4)

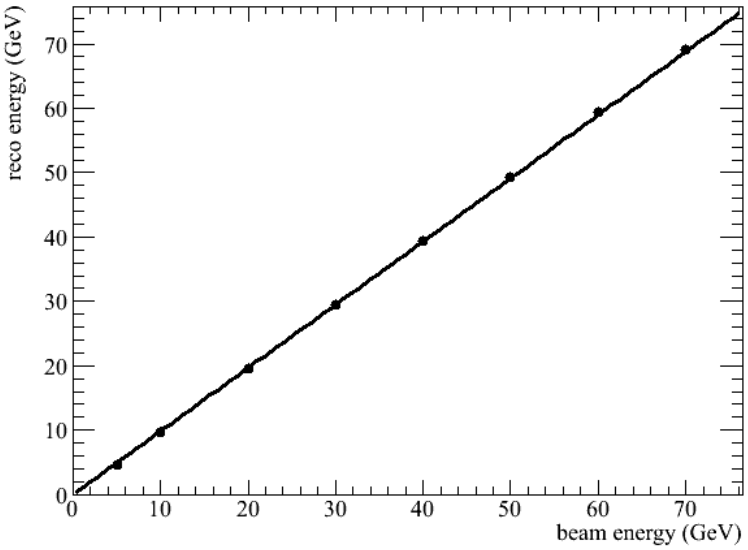


Saturation due to the high concentration of the electromagnetic part of the hadronic shower



Degradation of the resolution (ΔN/N) in higher energies due to this saturation.

Expectations with a SDHCAL 1/2

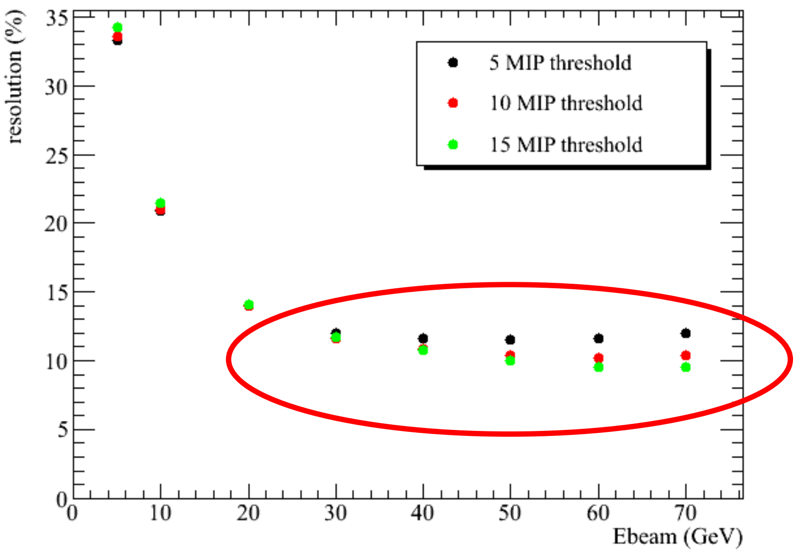


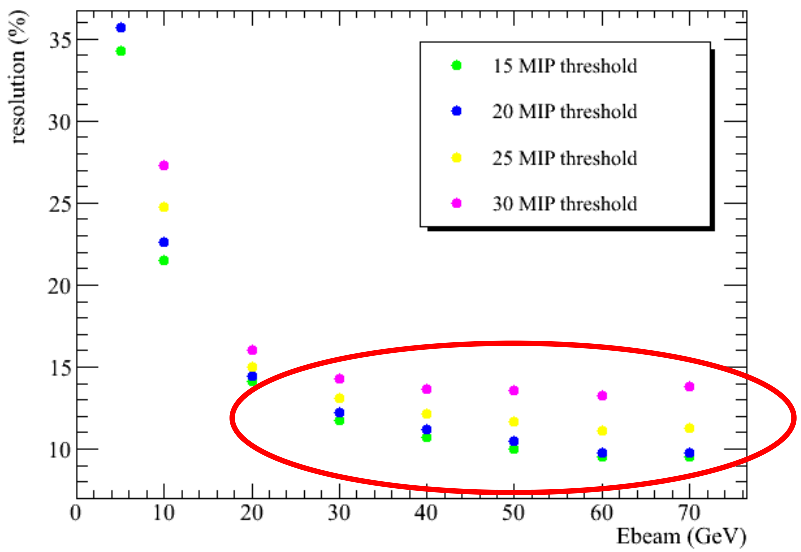
The effects of the saturation can be limited using a second higher threshold.

$$E_{rec}=w_0\cdot(N_0+w_1\cdot N_1)$$

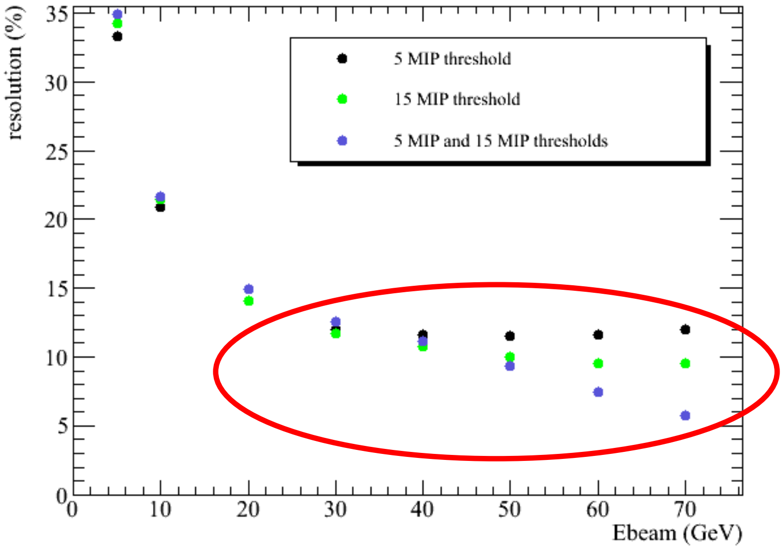
The weight of this threshold is computed using a MC optimization.

→ We see that a 15 MIP second threshold is the optimal choice.





Expectations with a SDHCAL 2/2



We can achieve even better results when using a combination of three thresholds.
We use both 5 and 15 MIP thresholds.

$$E_{rec}=w_0\cdot(N_0+w_1\cdot N_1+w_2\cdot N_2)$$

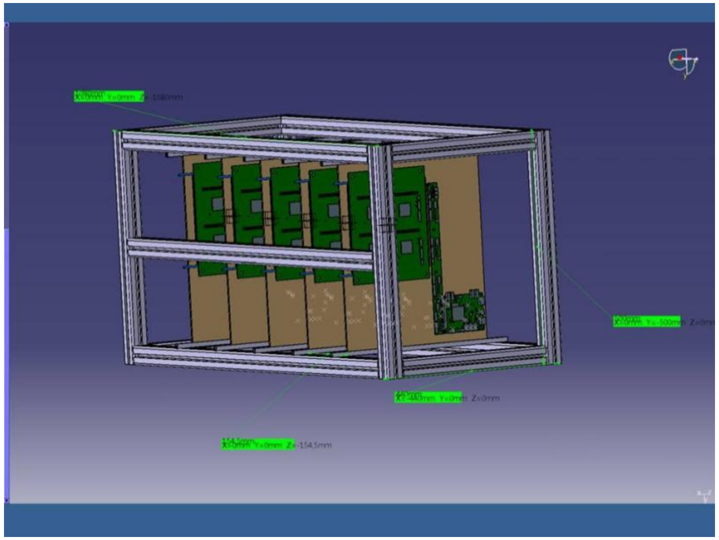
The two weights are computed using minuit and a MC optimization.

- This could be further improved, using energy dependent characteristics of the hadron shower in a multivariable analysis
- Example: include centre of gravity of hits along shower axis in probability distribution
- *Work in progress…*

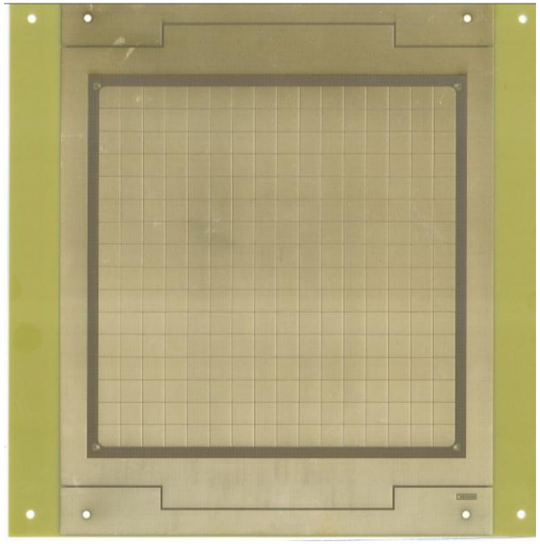
Improvement on spark protection

Protect ASICs against sparks with resistive electrodes while minimizing charge-up effect and hit multiplicity -> try different resistive configurations and select best

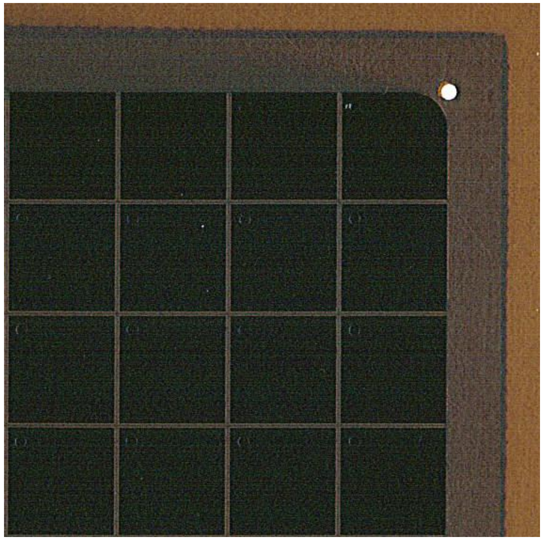
The prototypes will be tested on July at DESY



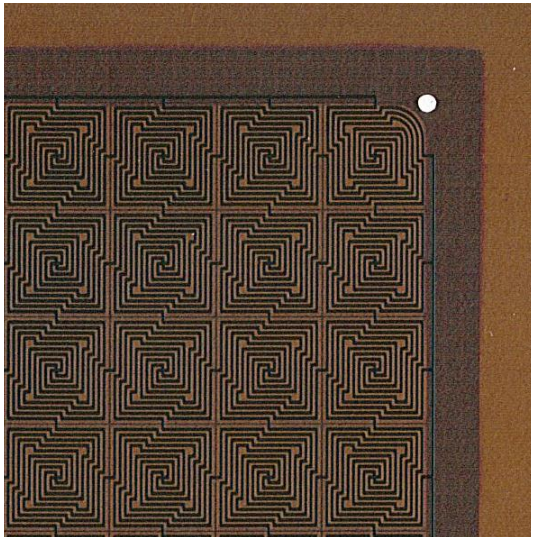
w/o resistive film



solution 1



solution 2



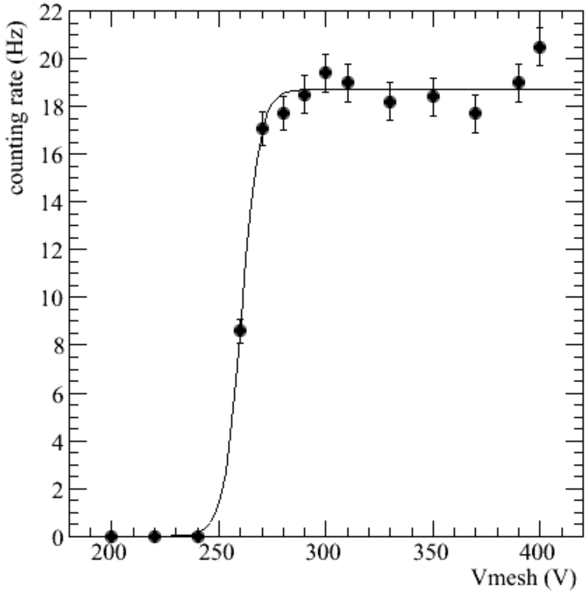
Conclusions

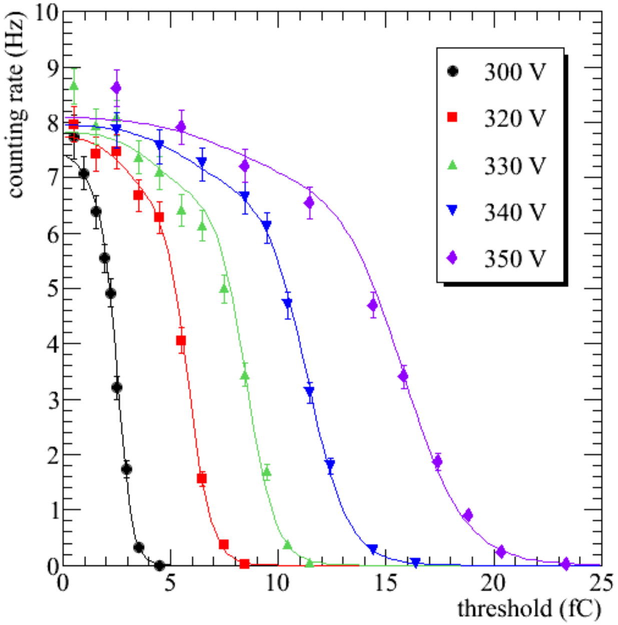
- R&D: Micromegas chambers for a high segmentation HCAL
  - Test beam proved an excellent performance
  - Study of the longitudinal profiles of a hadronic shower
    - Confirmation of the expected saturation in higher energies
  - MC study
    - Geant4 model tests
    - Offline compensation using 2 or 3 thresholds works
- Futur plans
  - Progression on the offline analysis
  - Improvement of the Micromegas chambers
    - Spark protection adding a resistive layer on the anode, instead of the diode networks
    - Construction of a larger area Micromegas with a single mesh

Backup

X-ray results of each individual chamber

- Before assembly into a 1x1m2 prototype, all chambers were tested at LAPP
- The tests used a gas mixture of Ar/CF4/iC4H10 95/3/2a 55Fe source



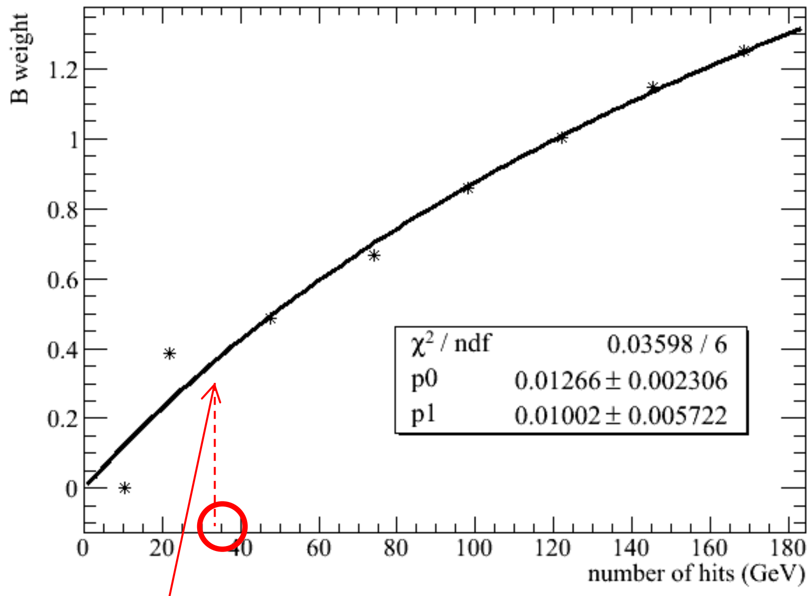


Parameterization of the weights

$E_{rec}=w_0\cdot(N_0+w_1\cdot N_1)$

For each energy we define the optimal value of w1 for a good energy reconstruction.

Then we parameterize the curve as a function of the total number of hits.



When reconstructing the energy, we apply the w1 value that corresponds to the total number of hits of each event.

$$E_{rec}=w_0\cdot(N_0+w_1(Nhits)\cdot N_1)$$